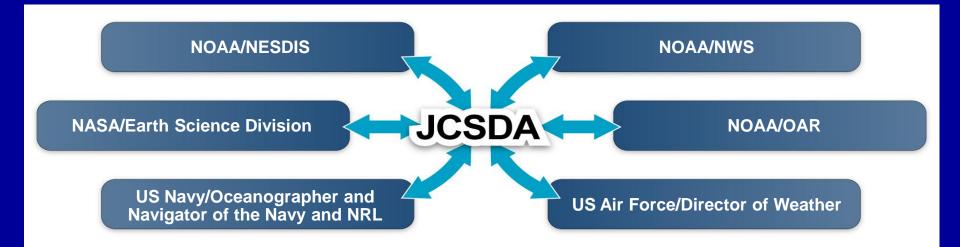# The Role of A-Train Data in Global Numerical Weather Prediction

Lars Peter Riishojgaard

Director, JCSDA

Overview

- JCSDA in brief
- Numerical weather prediction and societal benefits
- Satellite data and numerical weather prediction
  - Where does the skill come from?
  - Roles of research vs. operational data
- Numerical weather prediction and the A-Train

JCSDA Partners, Vision, Mission

NOAA/NESDIS	NOAA/NWS
NASA/Earth Science Division	**JCSDA**	NOAA/OAR
US Navy/Oceanographer and Navigator of the Navy and NRL	US Air Force/Director of Weather

Vision:

An interagency partnership working to become a world leader in applying satellite data and research to operational goals in environmental analysis and prediction

Mission:

...to accelerate and improve the quantitative use of research and operational satellite data in weather, ocean, climate and environmental analysis and prediction models.

JCSDA Science Priorities

*Overarching goal: Help the operational services improve the quality of their prediction products via improved and accelerated use of satellite data and related research. **R2O***

- Radiative Transfer Modeling (CRTM)
- **Preparation for assimilation of data from new instruments**
- Clouds and precipitation
- Assimilation of land surface observations
- Assimilation of ocean surface observations
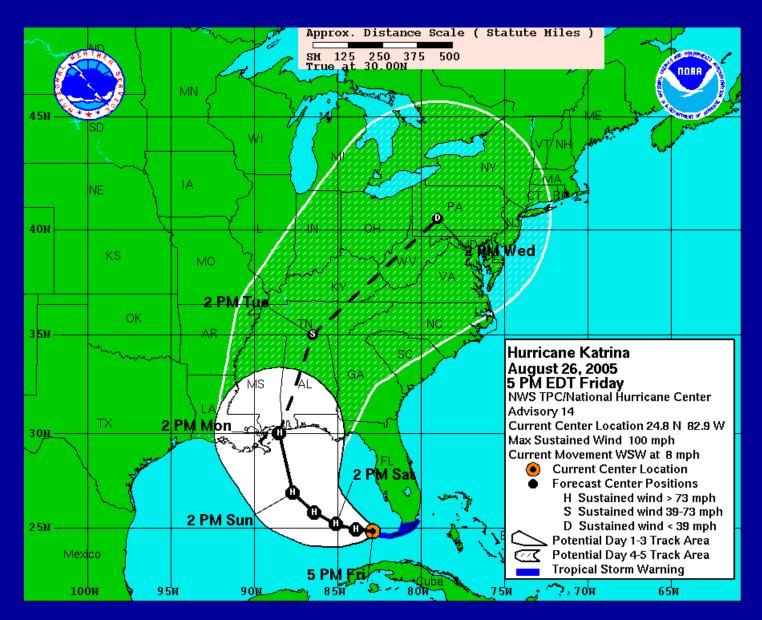- Atmospheric composition; chemistry and aerosol

Driving the activities of the Joint Center since 2001, approved by the Science Steering Committee
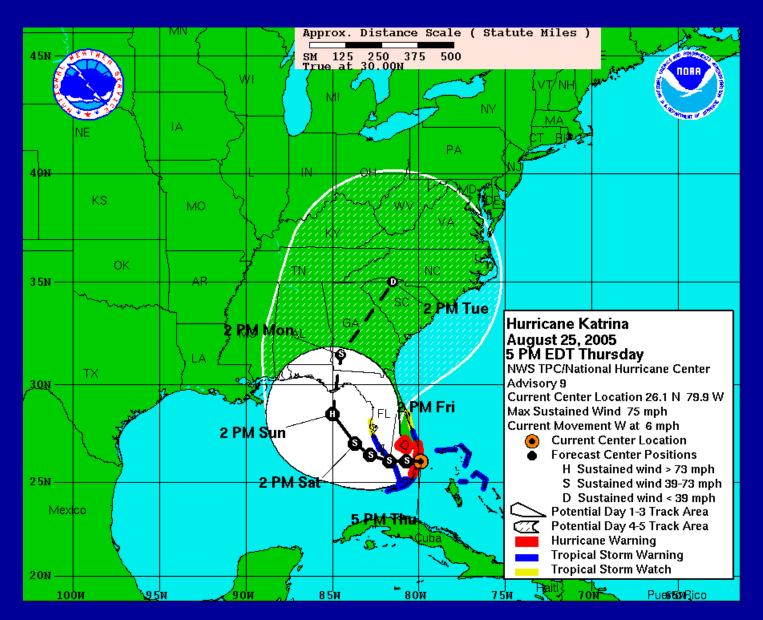
JCSDA short-term goal:
(adopted 03/2008)

- *"Contribute to making the forecast skill of the operational NWP systems of the JCSDA partners internationally competitive by assimilating the largest possible number of satellite observations in the most effective way"*

Two category 3-4 hurricanes

- "Galveston hurricane"
  - Landfall in Texas at 5 PM 09/08/1900
  - > $500M (2008 dollars) in property damage
  - ~10,000 fatalities (out of a population of ~40,000)
  - No satellite data, no upper air network, no NWP
- Katrina
  - Landfall (2nd) in Louisiana at 6 AM 08/29 2005
  - > $90B in property damage (2008 dollars)
  - > 1800 fatalities (out of a population of ~1.5M)
  - Extensive satellite and conventional observations, good forecast

A-Train Symposium, New Orleans

Approx. Distance Scale (Statute Miles)
SM 125 250 375 500
True at 30.00N

Hurricane Katrina
August 25, 2005
5 PM EDT Thursday
NWS TPC/National Hurricane Center
Advisory 9
Current Center Location 26.1 N 79.9 W
Max Sustained Wind 75 mph
Current Movement W at 6 mph

⬢ Current Center Location
● Forecast Center Positions
   H Sustained wind > 73 mph
   S Sustained wind 39-73 mph
   D Sustained wind < 39 mph
△ Potential Day 1-3 Track Area
▱ Potential Day 4-5 Track Area
■ Hurricane Warning
■ Tropical Storm Warning
■ Tropical Storm Watch

2 PM Tue
2 PM Mon
2 PM Fri
2 PM Sun
2 PM Sat
5 PM Thu

Economic value of weather forecasting

- Department of Commerce: "20% of overall US economy is weather sensitive": *~$3 trillion/year*

  - Impact to air and surface transportation, agriculture, construction, energy production and distribution, etc.

- Assume that <u>half of this is "forecast sensitive"</u>: *$1.5 trillion/year*
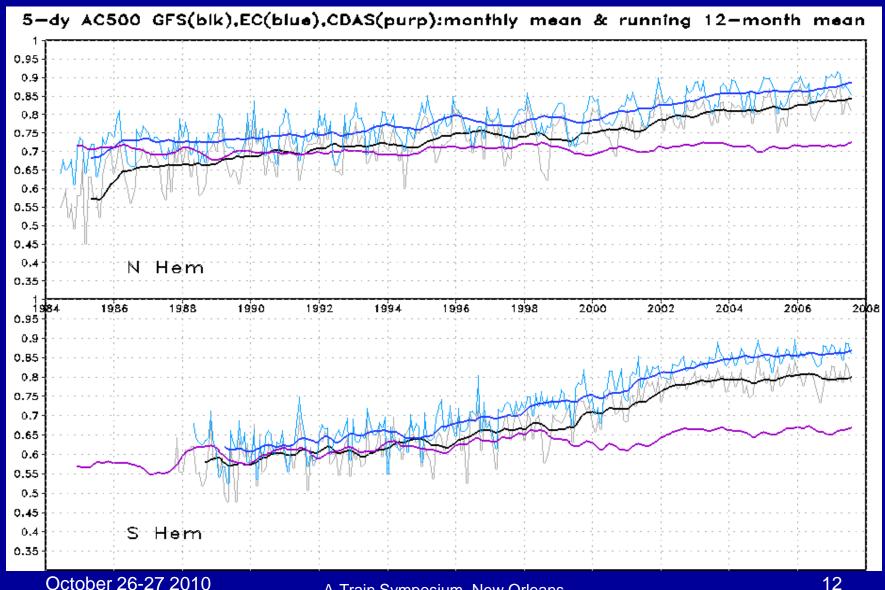
Value of weather forecasting (II)

- Assume that the <u>potential savings due to weather forecasting amount to 5%</u> of the "forecast sensitive total": *~$75B/year*

- Assume that the <u>savings are distributed linearly over the achieved forecast range</u> for the global NWP system:
  - 0 h useful forecast range => $0 in savings
  - 336 h useful forecast range => $75B in savings

- This implies that the value to the United States economy of NWP is *>200M per hour of forecast range per year* !

Why is JCSDA interested in this *(and why should all space agencies be interested in this)*?

- US falling behind internationally in terms of NWP skill
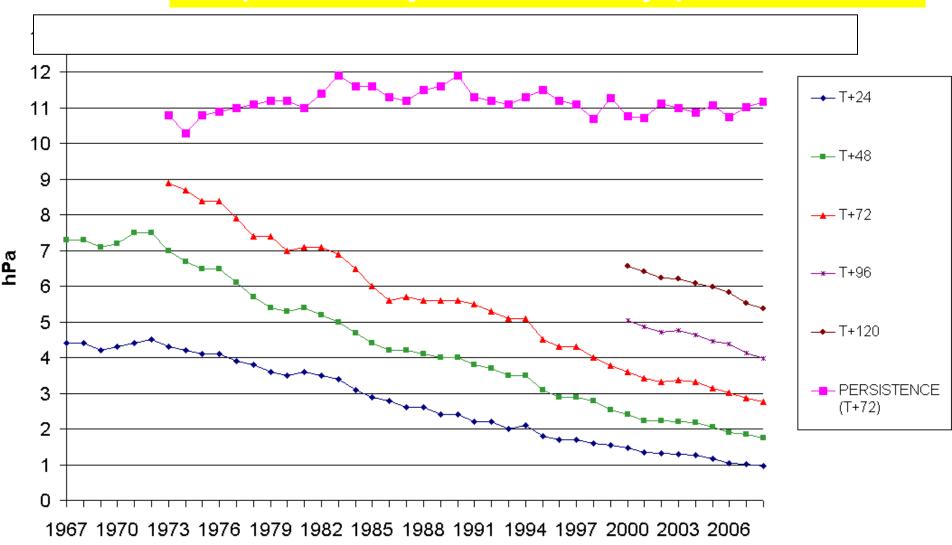
- Satellite data play a major role in NWP skill
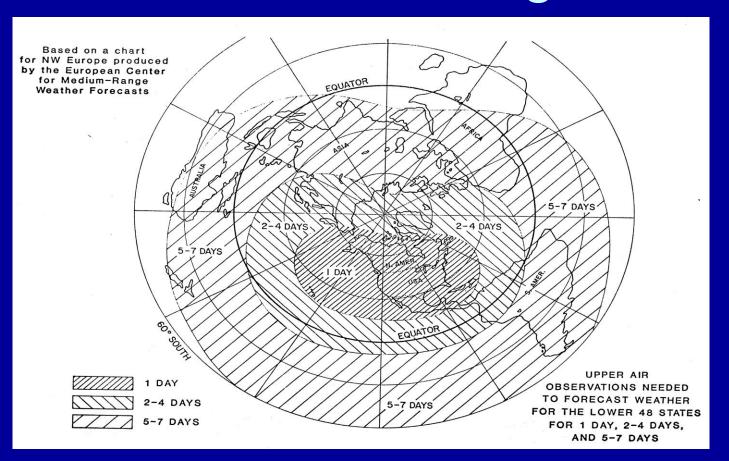
NOAA/NCEP vs. ECMWF skill over 20+ years

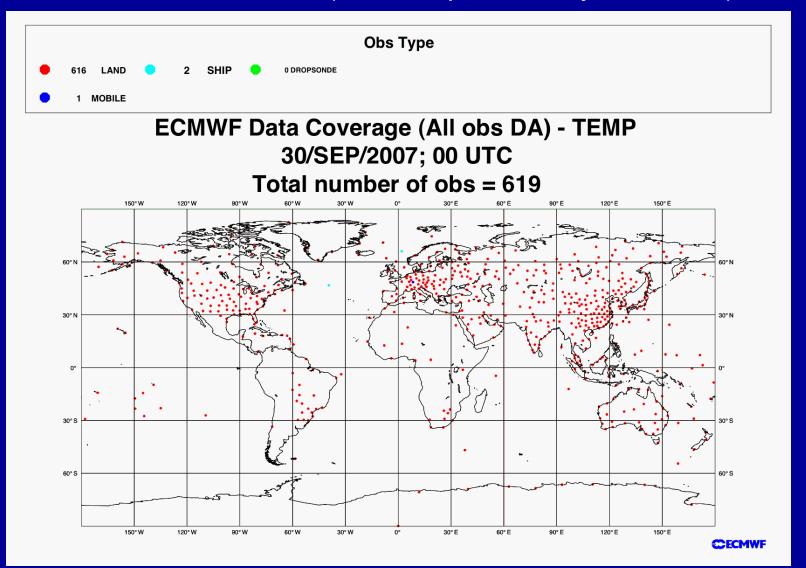5-dy AC500 GFS(blk),EC(blue),CDAS(purp):monthly mean & running 12-month mean

N Hem

S Hem

Performance Improvements

NWP requirements for upper-air data coverage
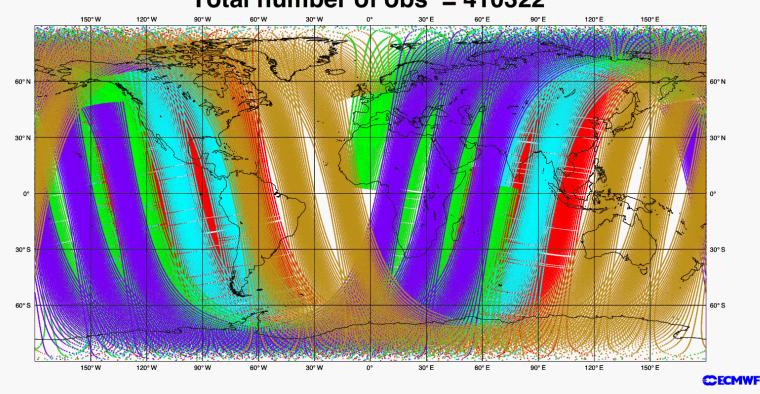
Conventional obs (u, v, T, q, vertically resolved)

October 26-27 2010

A-Train Symposium, New Orleans

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Example satellite data coverage (AMSU-A)

Obs Type

- 92993 N15-AMSUA
- 87846 N16-AMSUA
- 0 N17-AMSUA
- 95130 N18-AMSUA
- 64093 AQUA-AMSU
- 70260 METOP AMSU

ECMWF Data Coverage (All obs DA) - ATOVS
30/SEP/2007; 00 UTC
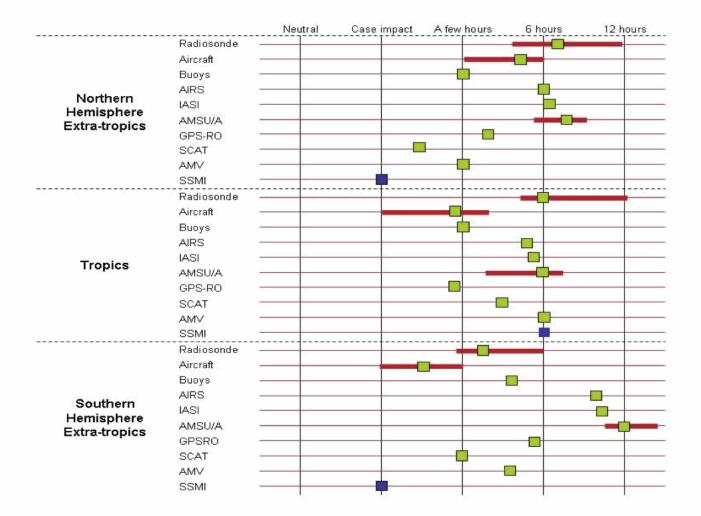**Total number of obs = 410322**

WMO and NWP skill

- Global NWP skill of major centers routinely compared under the auspices of WMO (OPAG-IOS under Commission for Basic System, Chair L. P. Riishojgaard)
  - Observing System Experiments
  - Adjoint Sensitivity
- Progress and results reviewed annually by WMO Expert Team
- Community-wide Impact Workshops (1997, 2000, 2004, 2008, 2012,…) used to synthesize experiments and develop official WMO statements of guidance
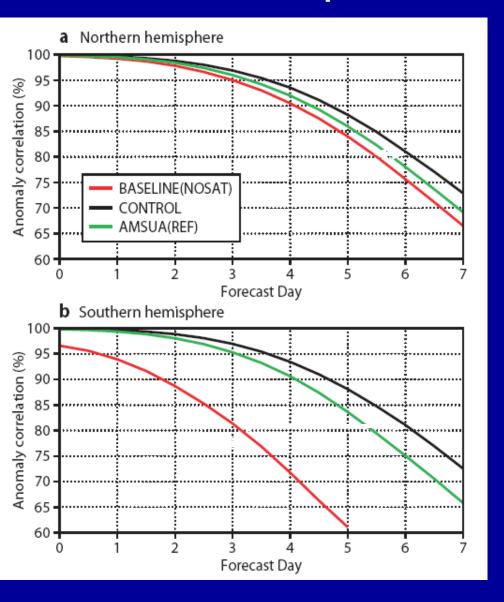
4ᵗʰ Workshop – impact summary (1)

Overall impact

short/medium range global NWP

Combined impact of all satellite data

a Northern hemisphere

b Southern hemisphere

Legend:
- BASELINE(NOSAT)
- CONTROL
- AMSUA(REF)

EUCOS Observing System Experiments (OSEs):

- 2007 ECMWF forecasting system,
- winter & summer seasons,
- Three experiments:
  1) no satellite data (NoSAT),
  2) NoSAT + 1 AMSU-A
  3) Control using all data
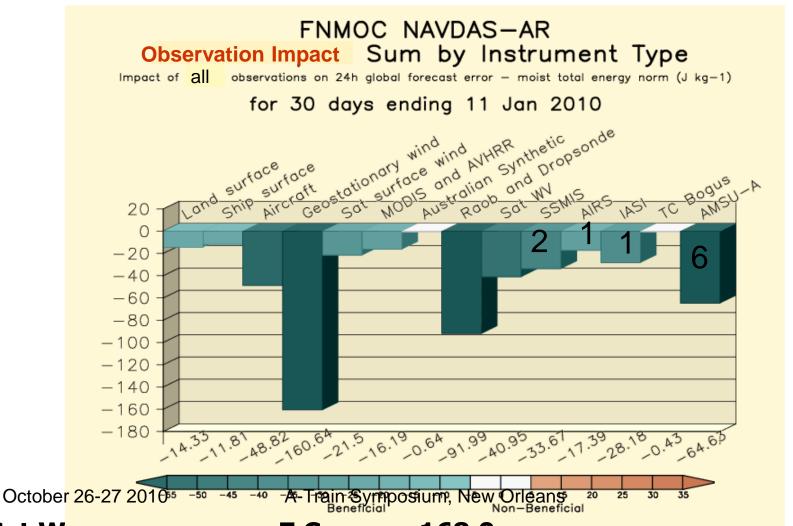
← 500 hPa *geopotential height* anomaly correlation

Slide courtesy of Erik Andersson, ECMWF

Satellite Data has become the single most important component of the global observing network for NWP

FNMOC NAVDAS−AR
Observation Impact Sum by Instrument Type
Impact of all observations on 24h global forecast error − moist total energy norm (J kg−1)
for 30 days ending 11 Jan 2010

October 26-27 2010   A-Train Symposium, New Orleans   20
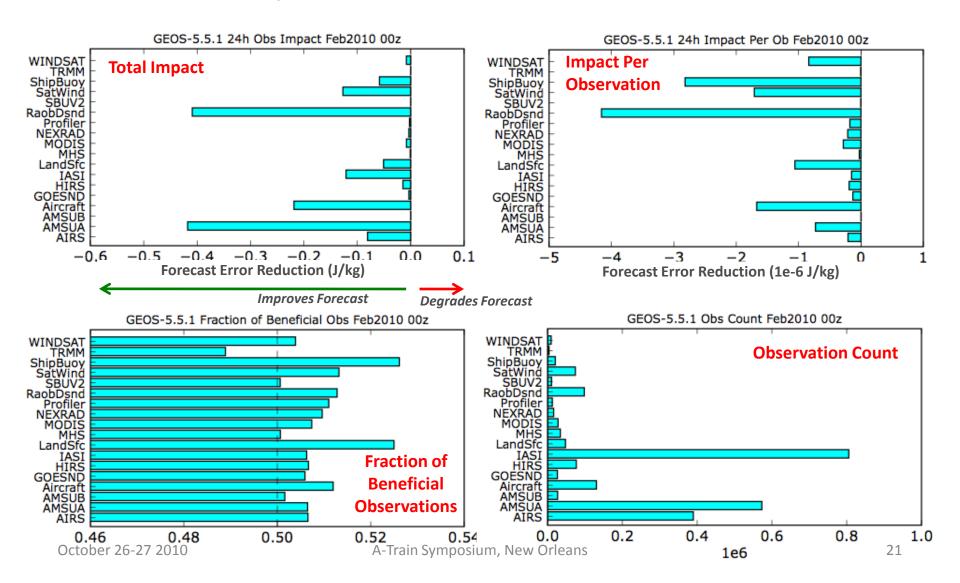
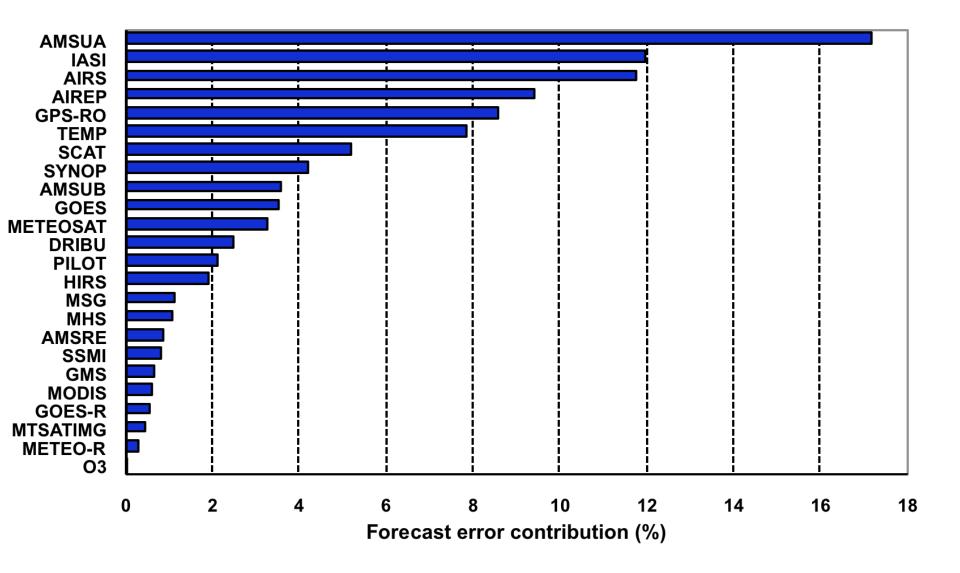**Σ Sat W**   **Σ Conv = -168.0**   **-143.9**

Impacts of Various Observing Systems in GEOS-5.5.1

Ron Gelaro, GMAO

24-hr Forecasts from 00z Analyses on 28 Jan – 02 March 2010
Adjoint-Based Global Forecast Error Measure

Forecast error contribution (%)

ECMWF

Impact of research data

- Depending on how impact is tallied, ~20-30% of total NWP skill is attributable to research (non-operational) satellite sensors
  - *contribution of several $B/year to the US economy alone*
  - *A-Train sensors account for most of this!*
- A-Train success has contributed to blurring the lines between "research" and "operational" satellite data:
  - WMO is relying heavily on a continued line of research sensors in its "Vision for the Global Observing System in 2025"
  - ESA's ADM/Aeolus research mission is being developed with operational data processing and dissemination, and data will be made available on WMO GTS

Impact of A-Train data (direct)

- AIRS
  - GOS mainstay; still work to be done; clouds, additional channels, water vapor channels, methodology

- MODIS
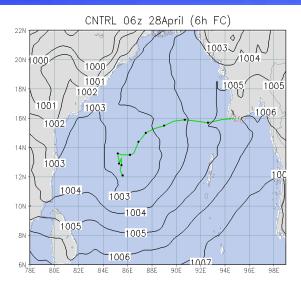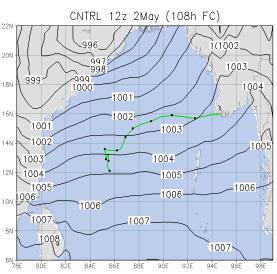 - Winds, direct assimilation of channels, surface characterization, AIRS algorithms
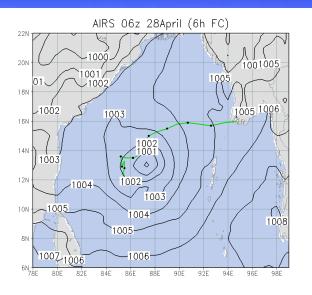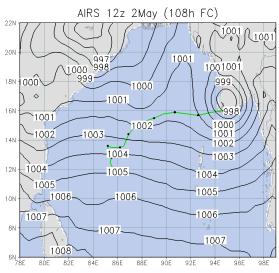
- AMSU-A
  - GOS mainstay

- AMSR-E
  - Precipitation, surface characterization

CNTRL 06z 28April (6h FC)

AIRS 06z 28April (6h FC)

CNTRL 12z 2May (108h FC)

AIRS 12z 2May (108h FC)

AIRS
Analysis
Well-defined
Cyclone
Green:
Observed
Track

AIRS 108-
hour
Forecast
(slp)

Green:
Observed
Track

CNTRL analysis (top) and
forecast (bottom): No Cyclone

Accurate landfall is produced in the forecasts initialized with AIRS: (Reale et al., 2009, Geophys. Res. Lett.)
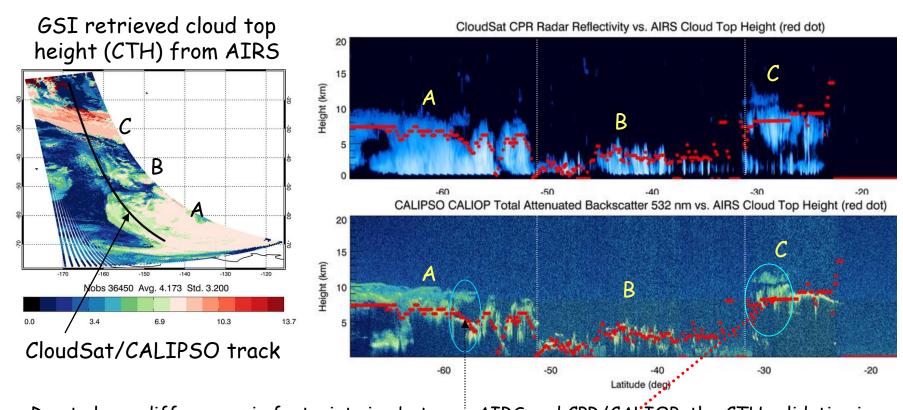
Impact of A-Train data
(indirect, through validation)

- Cloudsat

- CALIPSO

- OMI

- MLS

- …

CloudSat and CALIPSO are being used to evaluate and improve the NCEP/GMAO GSI cloud detection algorithm for AIRS

GSI retrieved cloud top height (CTH) from AIRS

CloudSat/CALIPSO track

- Due to large differences in footprint size between AIRS and CPR/CALIOP, the CTH validation is done only in regions A and C where the clouds are more uniform.
- In general, GSI-retrieved CTHs from AIRS are underestimated for optically thick clouds.
- Difficulties are seen in retrieving CTH in multi-layer clouds.

Some issues identified in GSI cloud-detection algorithm – impacts data selection choice for assimilation

Potential impact of A-Train data

- MISR
  - Potential for feature track wind observations with geometrically assigned heights
  - First generation had minimal impact due to sparse coverage
  - Next generation observations not yet tested
- OCO(-2)
  - Potential for first ever surface pressure measurement from space
  - Timeliness is an issue
  - Quality and impact of data is unknown
- OMI, MLS

Summary

- NWP has a large (and growing) economic impact
- Satellite data have a large (and growing) impact on NWP skill
- The way is which data from research platforms (including the A-Train) are used and have impact on operational NWP skill effectively make them indistinguishable data from operational platforms
- Research agencies such as NASA, JAXA and CNES have played (and hopefully will continue to play) a critical role in the continued development of the GOS and the user benefits that derive from it